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ABSTRACT

The study was designed to allow the investigation of the following research questions: (1) What are the magnitude and direction of measurable significant differences in meaningful learning orientation and meaningful understanding of physics concepts between students with learning cycle (LC) instruction and those with meaningful verbal reception learning (MVRL) instruction? (2) What are the magnitude and direction of measurable significant differences in meaningful understanding of physics concepts measured by conceptual questions, problem-solving, and mental models between students with the LC and MVRL instruction? (3) Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor of overall meaningful understanding of physics concepts? and (4) Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor for each sub-measure of meaningful physics understanding? This study was born from the idea that the Piagetian theory of learning is very similar to Ausubel's theory of meaningful learning. This study is really a comparison of the two theories, the blending of the two theories. (YDS)

# Ausubel and Piaget: A Contemporary Investigation

by
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# AUSUBEL AND PIAGET: A CONTEMPORARY INVESTIGATION

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## Purpose of Investigation

The study was designed to allow the investigation of the following research questions:

1. What are the magnitude and direction of measurable significant differences in meaningful learning orientation and meaningful understanding of physics concepts between students with learning cycle (LC) instruction and those with meaningful verbal reception learning (MVRL) instruction?
2. What are the magnitude and direction of measurable significant differences in meaningful understanding of physics concepts measured by (a) conceptual questions, (b) problem-solving, and (c) mental models between students with the LC and MVRL instruction?
3. Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor of overall meaningful understanding of physics concepts?
4. Which variable (reasoning ability, meaningful learning orientation, prior knowledge, or instructional treatment) is the best predictor for each sub-measure of meaningful physics understanding?

This study was born from of the idea that the Piagetian theory of learning is very similar to Ausubel's theory of meaningful learning. This study is really a comparison of the two theories, the blending of the two theories.

## Conceptual Framework

Meaningful learning is defined as "the formation of viable relationships among ideas, concepts, and information" (Williams & Cavallo, 1995). Students with a meaningful learning orientation attempt to make connections between concepts, whereas students not possessing a meaningful learning orientation memorize facts (Novak, 1984). Meaningful understanding is the product that may result when a person with a meaningful learning orientation and sufficient prior knowledge interacts with content that has the potential of being learned in a meaningful way (Novak, 1984).

The theory behind Ausubel's position espousing MVRL is based on several key concepts or processes: subsumption, progressive differentiation, superordinate learning, and integrative reconciliation. Subsumption is the process in which "new information often is relatable to and subsumable under more general, more inclusive concepts" (Novak & Gowin, 1984, p.97). Subsumption provides the "anchorage for new material". Progressive differentiation is the principle that "meaningful learning is a continuous process wherein new concepts gain greater meaning as new relationships (propositional links) are acquired" (Novak & Gowin, 1984, p. 99). Superordinate learning refers to the process in which a more general new concept subsumes previous subsumers (Novak, 1984). Previously learned concepts are subsumed and thus take on new meaning. Integrative reconciliation is the principle by which the learner "recognizes new relationships (linkages) between related sets of concepts or propositions" (Novak & Gowin, 1984, p. 103). Integrative reconciliation tends to break the isolation of concepts as relationships are formed between various previously isolated concepts or ideas. Often new propositional linkages between concepts displace misconceptions because a misconception is often simply the failure to integrate a particular concept.

Piaget believed that learners construct knowledge when a learner encounters input from the environment, the learner's schemes or mental structures incorporate the experiences (assimilation). If and when newly assimilated information conflicts with previously formed mental structures, the result is called disequilibrium (Marek & Cavallo, 1997). Disequilibrium motivates the learner to seek equilibrium. Regaining equilibrium or cognitive harmony results in what Piaget called accommodation. Accommodation is in the development of new mental structures. This "accord of thought with things" was what Piaget called adaptation (Piaget, 1963, p. 8). Thus, assimilation and accommodation represent the learner's adaptation to the environmental input. The learner must then organize the new or newly modified mental structure with previously existing mental structures. Organization is "the accord of thought with itself" (Piaget, 1963, p. 8). The LC, derived from Piagetian theory, consists of three phases: exploration, conceptual invention (or term introduction), and application (or expansion) (Marek & Cavallo, 1997).

## Methodology

A quasi-experimental design using a non-equivalent control-group was used in this research. Such a design is characterized by the non-random assignment of subjects to groups and the administration of pretests and posttests to each group.

The sample consisted of college students enrolled in two sections of an algebra-based, first semester, freshmen level, physics course. One of the two sections was randomly chosen to receive the LC treatment, while the other section received the MVRL treatment. Statistical methods should eliminate any initial differences between the groups due to non-randomization. The researcher taught both sections of the lectures and all labs to minimize any effect of teacher variable.

Physics concepts taught were the same for each treatment. In the LC students: (a) experimented with materials to gather data (exploration), (b) constructed a concept from those data (conceptual invention), and (c) expanded this idea or concept (expansion).

In MVRL, students were taught how to construct concept maps. Topics and concepts were taught from the most general (energy and matter) to the most specific (i.e. acceleration and specific heat). Students were given information about the various concepts through verbal instruction, advance organizers, and the textbook or lab manual. Students then organized this information when they constructed concept maps.

Three concepts were chosen for analysis in this study: forces, Archimedes' Principle/density, and heat. All topics in the course were taught according to the prescribed treatment so students were accustomed to the treatment style.

The Test of Logical Thinking was used to determine students' reasoning ability. The Learning Approach Questionnaire is a Likert scale instrument used to measure students' meaningful learning orientation. The Force Concept Inventory was used to assess conceptual understanding of forces. Multiple choice exams on Archimedes' Principle/density and heat were constructed to assess conceptual understanding. Students' problem solving was measured by their score on novel problems. Mental models were also used to assess student meaningful understanding. Students were asked to write everything that they knew about the three physics topics. Correct items from mental models were placed on templates and scored. A student's overall physics understanding score was obtained by summing the student's conceptual question score, problem solving score, and mental model score. This overall score was obtained pretest and posttest for each of the three concepts (forces, density/Archimedes' Principle, and heat). Pretest scores were used as covariates or as measures of prior knowledge.

## Data Analysis

For research question 1 to determine if any differences exist between the LC treatment and the MVRL treatment on the meaningful understanding variable, an analysis of covariance (one-way ANCOVA) was used. The effects of students' reasoning ability, prior knowledge, and meaningful learning orientation (all pretest measures) were covaried so that their effect upon their meaningful understanding was controlled. In order to determine if any differences exist between the LC and MVRL treatments on the meaningful learning orientation variable, a one-way ANCOVA was used. The effects of students' reasoning ability and their prior knowledge (pretest measures) were covaried so that any significant differences in meaningful learning orientation (dependent variable) between the groups were attributed to the treatments (LC or MVRL).

For research question 2 the procedure was the same as in question 1, except that it was done for each of the three measures of understanding separately. A one-way ANCOVA was used to determine if any differences exist between the LC and MVRL treatments on the meaningful understanding as measured by each instrument.

For research question 3, to determine which variable best explained students' overall meaningful understanding of physics concepts, a stepwise multiple regression was performed with students' reasoning ability, their meaningful learning orientation, their prior knowledge, and instructional treatment (LC or MVRL) entered as predictor variables in the regression analysis.

For research question 4, to determine which variable best explained students' sub-scale meaningful understanding of physics concepts, a stepwise multiple regression was performed as was done in question 3, but was used to predict student understanding on three understanding measures: (a) high level conceptual questions, (b) problem-solving, and (c) mental model scores.

## Results

### Question 1

Students from the two treatments did not significantly (at the .05 level) differ in their overall meaningful understanding of forces ($p$ = .079), Archimedes' Principle/density ($p$ = .097), or heat ($p$ = .374) (conceptual question score + problem solving score + mental model score). For all topics studied, the LC and MVRL treatments did not differ significantly in their ability to change the students' meaningful learning orientation ($p$ = .600 for forces, .830 for density/Archimedes' Principle, and .253 for heat).

Question 2

For forces, the students' concept scores, their problem solving scores, and their mental model scores did not differ significantly according to treatment ($p$ = .258, .079, and .092 respectively). There were no significant differences in the students' conceptual and mental model understanding of density/Archimedes' Principle between the LC and MVRL treatments ($p$ = .149 and .310 respectively). However, the LC and MVRL students did significantly differ in their density/Archimedes' Principle problem solving ($p$ = .006). The LC students had a greater mean understanding in density/Archimedes' Principle problem solving than did the MVRL students. The magnitude of the difference was 1.492, which represents a 25% improvement over the MVRL treatment mean.

For heat, there were no significant differences in the LC versus the MVRL treatments in conceptual and mental model understanding ($p$ = .871 and .396 respectively). However, the LC and MVRL treatments were significantly different in heat problem solving understanding ($p$ = .019). The MVRL students were greater problem solvers than the LC students. The magnitude of the difference was .972, which represents a 16% improvement over the LC treatment mean.

Based upon this research if forces was the topic being studied, it made no difference which treatment (LC or MVRL) was used. However if density/Archimedes' Principle was studied, the LC treatment was better at producing understanding in problem solving. However, when heat was studied, the MVRL treatment was better at producing understanding in problem solving. Treatment success was dependent upon topic studied.

Question 3

For overall meaningful understanding of the force concept (posttest), treatment was the best predictor although it was not significant at the .05 level ($r$ = -.263, $F$ = 3.561, $df$ = 48,

$p$ = .065) [$r$ = correlation; $F$ = F statistic; $df$ = degrees of freedom; $p$ = probability] . For posttest overall understanding of density/Archimedes' Principle, treatment was the best predictor

($r$ = -.198, $F$ = 1.878, $df$ = 46, $p$ = .177) although it was not significant. For posttest overall meaningful understanding of heat, the students' meaningful learning orientation was the best predictor ($r$ = .157, $F$ = 1.155, $df$ = 46 $p$ = .288) although it was not significant. Based upon these three findings, question 3 may not be formally answered as neither reasoning ability, learning approach, prior knowledge, nor treatment were significant predictors of overall meaningful understanding.

Question 4

Concept Understanding

For concept understanding it was found that for forces, prior knowledge was the most significant predictor in the model ($r$ =.587, $F$ = 21.861, $df$ = 48, $p$ = .000). However, reasoning ability was the next best predictor of force concept understanding ($r$ = .451, $F$ = 9.720, $df$ = 48, $p$ = .003). Together, reasoning ability and prior knowledge of force concept explain 45.6% of the variance in posttest understanding of force concepts. For density/Archimedes' Principle concept understanding, prior knowledge of density/Archimedes' Principle was the better predictor of students' posttest density concept understanding ($r$ = .406, $F$ = 6.479, $df$ = 46, $p$ = .014). Reasoning ability was the second best significant predictor ($r$ = .387, $F$ = 5.570, $df$ = 46, $p$ = .023) of students' density/Archimedes' Principle concept scores. Together reasoning ability and prior knowledge explain 25.7% of the variance in students' density concept scores. For heat concept understanding, reasoning ability was the only significant predictor of students' heat concept scores ($r$ = .348, $F$ = 6.355, $df$ = 46, $p$ = .015). Reasoning ability thus explains 12.1% of the variance in students' heat concept scores. In summary, students' conceptual understanding was best predicted by students' prior knowledge scores for forces and density/Archimedes'

Principle. However, students' heat concept understanding was best predicted by their reasoning ability.

Problem Solving

For predicting students' problem solving score for forces, the students' reasoning ability was the only significant predictor ($r = .391$, $F = 8.681$, $df = 46$, $p = .005$). Reasoning ability explained 15.3% of the variance in students' force problem solving. For density/Archimedes' Principle problem solving, treatment was the only significant predictor of students' problem solving scores ($r = -.277$, $F = 8.283$, $df = 46$, $p = .006$). The MVRL treatment correlated with decreased problem solving scores, while the LC treatment correlated with increased density/Archimedes' Principle problem solving scores. Treatment explained 7.7% of the variance in density/Archimedes' Principle problem solving scores. The students' reasoning ability was the better significant predictor of heat problem solving ($r = .356$, $F = 6.507$ , $df = 46$, $p = .014$). Treatment was the next best significant predictor of students' heat problem solving ($r = .338$, $F = 5.803$, $df = 46$, $p = .020$). A MVRL class correlated with greater problem solving scores. Together treatment and reasoning ability predicted 22.6% of the variance in heat problem solving scores.

Mental Models

None of the predictor variables (reasoning ability, learning approach, prior knowledge, or treatment) significantly predicted mental model scores. Thus, it is not possible to gain insight into predicting mental model scores from this work.

## Conclusions

### Conclusions for Question 1: Overall Meaningful Understanding

No measurable differences in meaningful understanding were found for forces, density/Archimedes' Principle, or heat. Separate *t*-tests comparing pretest and posttest scores of overall (conceptual + problem solving + mental model) understanding for each group revealed a significant ($p$ <.000) increase in meaningful understanding of the three physics concepts (Williams, 1997). Therefore, the LC and MVRL students improved their meaningful understanding. The students from the different treatments had nearly equal overall meaningful understandings. The results were similar because Piaget and Ausubel specified similar criteria for meaningful learning. *Both theories explain learning but in different terminology.* Following are a description of Piagetian theory explaining learning within the LC treatment and a description of Ausubelian theory explaining learning in the LC treatment. Figure 1 illustrates both theories for the LC.

Figure 1.
The Learning Cycle (LC) and Piagetian and Ausubelian Explanation
of How each Phase Led to Overall Meaningful Understanding

| Piagetian | LC | Ausubelian |
|---|---|---|
| | Exploration | |
| assimilation | | gives prior knowledge |
| disequilibrium | | subsumption |
| | Concept Invention | |
| accommodation | | progressive differentiation |
| | Concept Expansion (or application) | |
| organization | | superordinate learning |
| | | integrative reconciliation |

In the LC, students took this experience, constructed the concepts and formed greater meaningful understanding of these physics concepts. According to Piaget's (1963) theory (left hand column Figure 1) , the concrete experience allowed assimilation (incorporation of experiences into mental structures) which led to disequilibrium (conflict between mental structures). During the conceptual invention phase of the learning cycle, accommodation (change or development of new structures) occurred. Piaget called the processes of assimilation and accommodation adaptation. The student adapted to the input from the exploration. During conceptual expansion, the student organized the new mental structure with structures previously developed (organization). Thus, the LC students increased their meaningful understanding of the concept.

Ausubelian theory (right hand column Figure 1) can also be applied to explain students' learning during the LC. In the Ausubelian interpretation (Ausubel, 1963), the concrete experiences during the exploration provided the relevant prior knowledge necessary for meaningful learning. The exploration also provided the opportunity for subsumption during which new information was related to more general ideas. During conceptual invention, the students made links between data which encouraged them to orient their learning toward meaningful learning rather than rote. Students were encouraged to link new terminology to the phenomena observed during the exploration (progressive differentiation). Superordinate learning (new links cause one idea to subsume previous one) and integrative reconciliation (new links form between the old and new ideas) occurred during the conceptual invention phase of the LC.

Similarly, each theory can be used to explain how the MVRL treatment led to students' meaningful understanding. Following are a description of Piagetian theory explaining learning with the MVRL treatment and a description of Ausubelian theory explaining learning in the MVRL treatment. Figure 2 illustrates both theories for MVRL.

According to Piaget (Piaget, 1963), the students who were in transition or who were formal operational assimilate input from verbal instruction (left column of Figure 2). Students were told to construct concept maps relating various aspects of the concept(s). The construction of the concept maps were based upon reading passages from the textbook. Students struggled with ways to relate the items in the passages from the textbook for additional assimilation. The laboratories provided the opportunity for the students to become disequilibrated and to accommodate to the data. Organization occurred during the students' efforts to construct a concept map that related their thoughts about additional concepts to their thoughts about the new phenomena or concept studied.

Figure 2.
Meaningful Verbal Reception Learning (MVRL) and Piagetian and Ausubelian Explanations of How each Phase Led to Overall Meaningful Understanding

| Piagetian | MVRL | Ausubelian |
|---|---|---|
| | | verbal instruction |
| | assimilation* | prior knowledge |
| | | subsumption |
| | | advance organizers & |
| | | concept maps |
| | assimilation* | subsumption |
| | | progressive differentiation |
| | | laboratories |
| | disequilibrium | subsumption |
| accommodation | | progressive differentiation |
| | | advance organizers & |
| | | concept maps |
| | organization | superordinate learning |
| | | integrative reconciliation |

* for formal operational sample only.

According to Ausubel (1963), prior knowledge and subsumers for concepts were provided by verbal instruction (right column Figure 2). Students were encouraged to orient their learning away from rote when they were asked to construct concept maps. Laboratories and concept maps also promoted subsumption and progressive differentiation as new links were created. More advance organizers or verbal instruction caused the students to link items to other, less specific items (superordinate learning). Furthermore, integrative reconciliation was accomplished as additional maps were constructed or revised by the student.

Piagetian *and* Ausubelian theory can explain how the students in each treatment achieved overall meaningful understanding. It appears that Piaget *and* Ausubel have viable theories of learning which appear to explain learning by using different terms. More research needs to be conducted to validate this premise.

Conclusions for Question 1: Meaningful Learning Orientation

The remaining part of question 1 deals with the meaningful learning orientation of the students in the two treatments. For all topics, the LC and MVRL students' meaningful learning orientation did not differ significantly. Ad hoc *t*-tests showed that there was not a significant change in meaningful learning orientation scores (pretest to posttest) for *either* treatment. Neither increased or decreased their tendency to learn meaningfully. Perhaps this is evidence that it is not possible to change the learning orientation of college physics students during such a short treatment. Dickie (1994) found that students' tendency to learn by rote *increased* after a college physics class. Perhaps the students from the treatments in this study left the courses with a greater tendency to learn meaningfully than if they had been in a course that was taught traditionally.

Conclusions for Question 2

There were no significant differences between the LC and MVRL treatments for students' concept understanding or mental model understanding of forces, density/Archimedes' Principle, and heat. These findings provided more evidence for the idea that Piagetian and Ausubelian theories are similar theoretically if their end-products (students' conceptual understanding and mental model knowledge) are not significantly different.

There were no statistically significant differences among treatments on the problem solving for forces. However for density/Archimedes' Principle data, the LC students had a 25% improvement in problem solving over the MVRL students' mean scores. This may simply indicate weaknesses in curricula for the two treatments. The LC exploration was a density problem solving activity similar to those on the assessment instrument. Perhaps the MVRL on density/Archimedes' Principle did not to provide suitable anchors, thus creating less problem solving ability by its students. A Piagetian explanation for the MVRL curricular weakness for density/Archimedes' Principle might be that there was no assimilation because of a lack of previous experience. A lack of experience could possibly have caused the MVRL students to lag behind in density/Archimedes' Principle problem solving.

For heat data, the MVRL students had a 16% improvement in problem solving over the LC students. From day one in the MVRL treatment, students were relating concepts to energy and heat. These students simply may have thought about heat more and made more connections which increased their problem solving ability. The LC students did not have an earlier LC to provide anchors about heat. Thus, the LC students had less experience with heat (according to Piaget) or less prior knowledge about heat (according to Ausubel). Whether explained in Piagetian terms (no assimilation occurred) or in Ausubelian terms (no subsumers were available), the LC students solved fewer problems on the heat concept than the MVRL students did. Why the same differences between treatment due to treatment weakness or strength did not appear on the conceptual and mental model assessments are unknown.

Conclusions for Question 3

Neither treatment, nor reasoning ability, nor meaningful learning orientation, nor prior knowledge were significant predictors of overall physics (concept + problem solving + mental model) understanding at the .05 level. Very little may be concluded from the results of question 3 aside from the fact that more research must be conducted with other instruments and well-tested curricula to determine what variables are the strongest predictors of overall physics understanding.

Conclusions for Question 4

For forces and density/Archimedes' Principle data, students' prior knowledge was the best predictor of concept understanding while reasoning ability was the next best predictor. Reasoning ability was the only significant predictor of concept scores for heat. Without prior experience, conceptual understanding decreased for forces and for density/Archimedes' Principle. That is to be expected by both theories, for without assimilation or subsumers, meaningful learning does not occur (Ausubel); or without adequate reasoning ability, abstract concepts such as forces, density/Archimedes' principle, and heat can not be learned (Piaget).

For problem solving understanding of force and heat concepts, reasoning ability was the best predictor. This can be explained if Piagetian reasoning ability and the Ausubelian term "potentially meaningful" have similar meaning. If forces and heat were presented in a potentially meaningful way, then according to Ausubel meaningful learning measured by solving problems could occur. If forces and heat were presented to formal operational learners, then according to Piaget problem solving understanding could occur. For heat, the next best predictor of problem solving was treatment, with MVRL treatment correlating with greater heat problem solving. For density/Archimedes' Principle, the best predictor was treatment, with the LC treatment correlating with greater density/Archimedes' Principle problem solving. This finding is consistent with the findings of question 2. For density/Archimedes' Principle, this may be explained by the apparent weakness of MVRL combined with the strength of the LC and the apparent strength of MVRL presentation of heat combined with the apparent weakness of the LC.

None of the predictor variables were significant predictors of the knowledge measured by mental models. Mental models should be examined further as tools to measure meaningful understanding of college physics students.

The analysis of predictor variables for concept understanding and problem solving further support the idea that Piagetian and Ausubelian theory are similar in their explanation of how learning occurs. All variables mentioned in theories by Piaget and Ausubel were not significant predictors for concept understanding or problem solving, so exact correlations of the theories are not yet possible based on the findings of this research.

## Significance of this Study for Future Research and Instruction

Students need to be instructed in a way that promotes the abandonment of rote learning in favor of more meaningful learning approaches (McKinney, 1993; NSTA, 1993; Aldridge & Strassenburg, 1995). Students' tendency to learn more and more meaningfully and with meaningful understanding are desired outcomes of physics education. Thus, this study is significant to physics educators interested in improving students' meaningful understanding.

This study is significant in that according to this research, there were no significant differences between the Piagetian-based LC and the Ausubelian-based MVRL for college students' meaningful understanding of physics concepts. What the results of this research suggested is that although Piaget and Ausubel used different terminology to explain learning, these theories are very similar. This research is novel in that it attempted to blend the two theories. Far more questions were raised than have been answered. For example, where is the disequilibrium in Ausubel's theory? What is the motivating factor in Ausubel's theory that compares to the disequilibrium in Piaget's theory? Is the learning orientation sufficient to motivate the learner to make the necessary connections? If it is, what is the motivating force for organization in Piagetian theory? Further research is necessary to obtain answers to these critical questions.

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